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Construction of New Standardized Attribute Control Chart based on defects per million opportunities

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ABSTRACT

To understand the concepts of Six Sigma, the concepts of Defects Per Unit (DPU) and Defects Per Opportunities (DPO) need to be introduced. DPU and DPO have different implications from attribute and variable data perspectives. The aim of this paper is to Construction quality control chart, which is Standardized attribute control chart based on defects per million opportunities (dpmo) to justify the efficiency and sensitively of the new chart for detecting are out of control cases. Using example, it was found that the examined processes were in control on both charts .The chart suggested herein may be useful for companies practicing Six Sigma process. These charts can be used to replace existing Shewhart control charts implemented when companies first started implementing Six Sigma.

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Introduction: I.

The main objective of any productivity operation is to get high quality materials and conform to the specifications so as to meet consumer desires. The quality is a principle in which some may think it is new, but it is as old as human, because the man was still in a permanent search for a good thing, and paying attention to the quality .Quality has great care in the industrialized developed countries being of economies exporter seek to control the foreign markets. In the early twentieth century, quality control practices were limited to inspecting finished products and removing defective items. But this all changed as the result of the pioneering efforts of a young engineer named Walter A. Shewhart. In 1924 Shewhart prepared a memorandum that included a set of principles that are the basis for what is known today as process control. And his memo also contained a diagram that would be recognized as a statistical control chart. Continuing his work in quality at Bell Telephone Laboratories in USA until his retirement in 1956, he brought together the disciplines of statistics, engineering, and economics and in doing so changed the course of industrial history. Shewhart is recognized as the father of statistical quality control.[4]

The recent development in the field of quality control charts is the composition of new quality control charts dependent in decision taken on more than one point to overcome some of the deficiencies found in the Shewhart's chart, many researches has been conducted for this purpose, prompting many researchers to continuous think to fulfill this goal.

In Iraq, the Iraqi researchers contributed in this area by publication of many researches and studies about quality control.

Quality Control Charts[2] [3]

A quality control chart (also called process chart) is a graph that shows average for the data (output) or the product fall within the common or normal range of variation if the process is under statistical control. Quality control charts were first invented by Walter A. Shewhart, and developed by him and his associate. He published a complete exposition of control charts in 1931. Which used by Shewhart in the construction of his charts. He concluded that a distribution can be transformed into a normal shape by estimating its mean and standard deviation. Shewhart`s idea was whether the production process is going well and naturally and the points plotted on the chart follow a normal distribution. For these reasons, Shewhart resorted to use the normal distribution in the construction of his charts.

Shewhart control charts consist of three parallel lines which are:

1. Center Line (or target line) of the control chart is the mean, or overall average, of the quality characteristic that is being measured, and symbolized as T.
2. The upper control limit (UCL) is the maximum acceptable variation from the mean for a process that is in a state of control.

Mathematically expressed as: $UCL = T + 3\sigma$

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3. Lower control limit (LCL) is the minimum acceptable variation from the mean for a process that is in a state of control.

Mathematically expressed as: $LCL = T - 3\sigma$

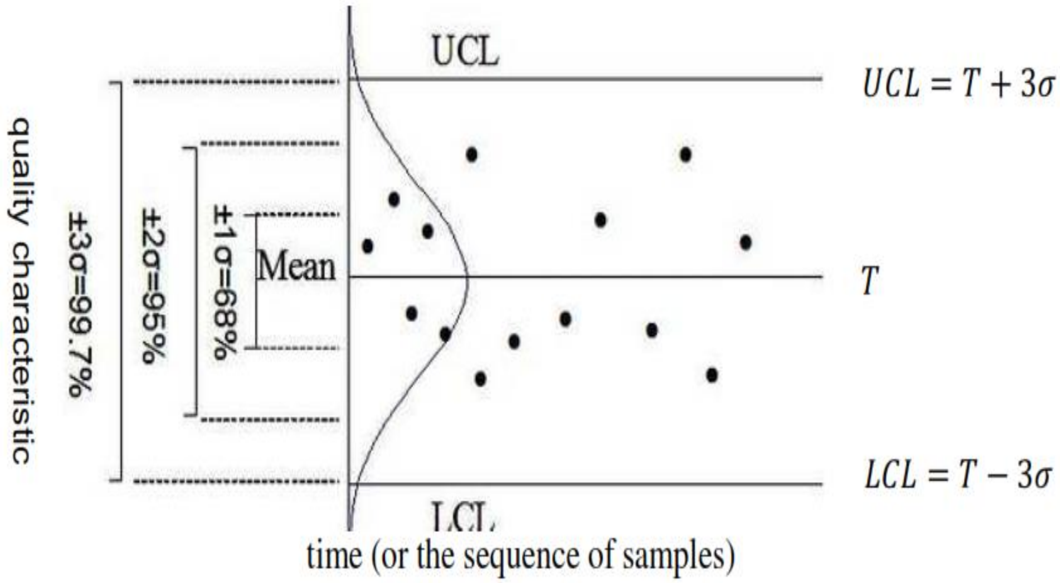

Figure 1: Normal distribution of continuous variables

Classification of control charts[3] [4] [2]

Control charts may be classified into two main types, which are:

1. VARIABLE CONTROL CHARTS

These charts are used in process control of products when the items produced are measurable (in one of the units of measurement).

The most important types of variable control charts can be divided into two types:

I. Shewhart Variable Charts: the most familiar Shewhart charts are

a. Average – Chart (or $\bar{x}$- chart)
b. Standard Deviation- Chart (S-chart)
c. Range - Chart (R-chart)
d. Individual – Chart(X- chart).
e. Median chart (Me- chart).

II. **Non-Shewhart Variable Charts**[3] [2]

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a. Cumulative sum control chart(CUSUM-chart)
b. Moving average chart (MA-chart)
c. Moving range chart (MR-chart)
d. Geometric Moving average chart (GMA-chart)

2. Attributes Control Charts

Attribute control charts are used when:
(a) Measurements are not possible (e.g., defect such as dented cans).
(b) Measurements are not practical (e.g., lengthy chemical analyses of raw products).
(c) Several characteristics are combined on one chart (e.g., counts of different kinds of defects). In this case, the various characteristics can be lumped together into a single chart, or at most two or three charts, each covering that group of characteristics which reflects their importance such as minor, major, and critical.[4] [2]

The attribute control charts can be classified into: [2] [3]
a. Defective or nonconforming chart. p-chart (fraction nonconforming)
b. np-chart (number nonconforming).
c. Defects or nonconformities charts. C-chart (number of nonconformities).
d. U-chart (average number of nonconformities).

Six sigma and DPMO[6] [5]

Sigma is a letter in the Greek alphabet that has become the statistical symbol and metric of process variation. The sigma scale of measure is perfectly correlated to such characteristics as defects-per-unit, parts-per-million defectives, and the probability of a failure. Six is the number of sigma measured in a process, when the variation around the target is such that only 3.4 outputs out of one million are defects under the assumption that the process average may drift over the long term by as much as 1.5 standard deviations. The defect rate, denoted by p, is the ratio of the number of defective items which are out of specification to the total number of items processed (or inspected). Defect rate or fraction of defective items has been used in industry for a long time. The number of defective items out of one million inspected items is called the ppm (parts-per-million) defect rate. Sometimes a ppm defect rate cannot be properly used, in particular, in the cases of service work. In this case, a DPMO (defects per million opportunities) is often used. DPMO is the number of defective opportunities which do not meet the required specification out of one million possible opportunities. For calculating DPMO we need the following:

I-Defects per Unit (DPU)[6]
The average number of defects per unit. The ratio of defects to unit is the universal measure of quality.

Given:

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D: number of Defects

U: number of Units

Formula:

$$DPU = \frac{\text{total number of Defects}}{\text{total number of Units}} = \frac{D}{U} \quad ...(1)$$

II-DEFECTS PER OPPORTUNITIES (DPO)

We may calculate the defects per opportunity by this formula

$$DPO = \frac{\text{DPU}}{\text{m}} \quad ...(1)$$

Where *m* is the number of independent opportunities for nonconformance

Per unit

III-DEFECTS PER MILLION OPPORTUNITIES (DPMO)
We may calculate the defects Million per unit opportunity by this formula

$$DPMO = \text{DPO} * 1000000 \quad ...(3)$$

<u>Construction Defects Per Million Opportunities (DPMO) chart:</u>[6]

The DPMO chart is particularly useful in the monitoring of manufacturing operations for any process that has products with large numbers of defect opportunities. The defects per million opportunities (DPMO) chart are a relatively new attributes control chart, certainly as compared to Shewhart chart. For Construction defects per million opportunities, we need steps following:

First step
Calculate the defects per unit for each subgroup based on first formula:

$$DPU_i = \frac{d_i}{n_i}$$

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Where

d_i : Count of defects in subgroup *i*.

n_i : Sample size of subgroup *i.*

h: Number of subgroups.

Second step

Calculate the defects per opportunities based on second formula:

$$DPO_i = \frac{DPU_i}{m}$$

Where *m* is the number of independent opportunities for nonconformance Per unit

Third step

Calculate the defects per million opportunities for each subgroup based on third formula:

$$DPMO_i = DPO_i * 1000000$$

Forth step

Calculate the central line and control limits for this chart

$$\left.\begin{aligned} LCL &= \overline{DPMO} - 3\sqrt{\frac{\overline{DPMO} * 1000000}{n_i * m}} \\ CL &= \overline{DPMO} = \frac{\sum_{i=1}^{h} DPMO_i}{h} \\ UCL &= \overline{DPMO} + 3\sqrt{\frac{\overline{DPMO} * 1000000}{n_i * m}} \end{aligned}\right\} \quad \ldots (4)$$

The points plotted are the values of quality characteristic ($DPMO_i$ of the *i*-th Subgroups).

Construction Standardized control chart based on defects per million opportunities[6] [1] [5]

Dealing with attributes data in the short production run environment is extremely simple; the proper method is to use a standardized control chart for the attribute of interest. This method will allow different part numbers to be plotted on the same chart and will automatically compensate for variable sample size.

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Such a control chart has the center line at zero, and upper and lower control limits of +3 and −3, respectively. The variable plotted on the chart is:

$$Z_i = \frac{DPMO_i - \overline{DPMO}}{\sqrt{\frac{\overline{DPMO} \;*1000000}{n_i * m}}} \quad \text{.... (5)}$$

Application

In this section, we apply both charts. The data collected on a hypothetical example – but one indicative of a typical PCB assembly process to the new suggested charts as well as to some existed charts .We used (Statgraphics 4.0 and Microsoft Excel) for computation purpose. The data consists of (24) subgroups and each assembly has 3,000 opportunities for defects and 100 PCB assemblies are inspected each day.[6]

Table1: calculation per million opportunities for each subgroup

Sub groups	Defects	DPU	DPO	DPMO	$Z_i = \frac{DPMO_i - \overline{DPMO}}{\sqrt{\frac{\overline{DPMO} \;*1000000}{n_i * m}}}$
1	**19**	**0.19**	**0.0000633333**	**63.33333**	**-0.25979**
2	**19**	**0.19**	**0.0000633333**	**63.33333**	**-0.25979**
3	**22**	**0.22**	**0.0000733333**	**73.33333**	**0.408263**
4	**19**	**0.19**	**0.0000633333**	**63.33333**	**-0.25978**
5	**21**	**0.21**	**0.0000700000**	**70**	**0.185582**
6	**17**	**0.17**	**0.0000566667**	**56.66667**	**-0.70514**
7	**29**	**0.29**	**0.0000966667**	**96.66667**	**1.96703**
8	**13**	**0.13**	**0.000043333**	**43.33333**	**-1.59587**

			3		
9	**15**	**0.15**	**0.0000500000**	**50**	**-1.1505**
10	**17**	**0.17**	**0.0000566667**	**56.66667**	**-0.70514**
11	**16**	**0.16**	**0.0000533333**	**53.33333**	**-0.92782**
12	**17**	**0.17**	**0.0000566667**	**56.66667**	**-0.70514**
13	**17**	**0.17**	**0.0000566667**	**56.66667**	**-0.70514**
14	**15**	**0.15**	**0.0000500000**	**50**	**-1.1505**
15	**23**	**0.23**	**0.0000766667**	**76.66667**	**0.630944**
16	**22**	**0.22**	**0.0000733333**	**73.33333**	**0.408263**
17	**27**	**0.27**	**0.0000900000**	**90**	**1.521668**
18	**17**	**0.17**	**0.0000566667**	**56.66667**	**-0.70514**
19	**20**	**0.20**	**0.0000666667**	**66.66667**	**-0.0371**
20	**22**	**0.22**	**0.0000733333**	**73.33333**	**0.408263**
21	**20**	**0.20**	**0.0000666667**	**66.66667**	**-0.0371**
22	**23**	**0.23**	**0.0000766667**	**76.66667**	**0.630944**
23	**30**	**0.30**	**0.0001000000**	**100**	**2.189711**

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24	**24**	**0.24**	**0.0000800000**	**80**	**0.853625**

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Construction Defects Per Million Opportunities chart:

The target line for this chart represents the overall average of the DMPO, which is (CL= $\overline{DPMO}$ =67.2222), and the control limits have been put at ($\pm 3\sqrt{\frac{\overline{DPMO}*1000000}{n_i * m}}$) from the target line. The value of control limits are (LCL=22.31) and (UCL=112.129)

$$CL = \overline{DPMO} = \frac{\sum_{i=1}^{h} DPMO_i}{h} = \frac{1613.33}{24} = 67.2222$$

$$LCL = \overline{DPMO} - 3\sqrt{\frac{\overline{DPMO}*1000000}{n_i * m}} = 67.2222 - 3\sqrt{\frac{67.2222*1000000}{100*3000}} = 22.31$$

$$UCL = \overline{DPMO} + 3\sqrt{\frac{\overline{DPMO}*1000000}{n_i * m}} = 67.2222 + 3\sqrt{\frac{67.2222*1000000}{100*3000}} = 112.129$$

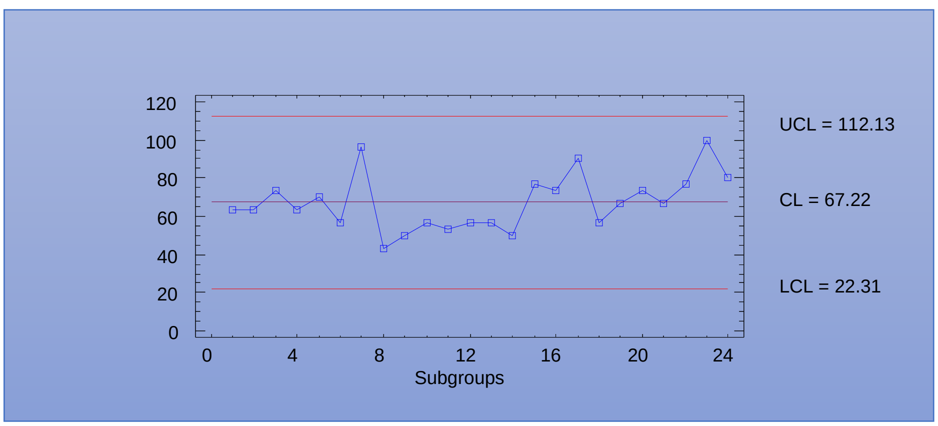

Figure 2 : **defects per million opportunities – chart**

From figure (2) we observe that all points are located within the control limits according to the statistical analysis which means that the data of table (1) are appropriate for this chart. This means that we can rely on the chart and use it for the future to control.

Construction Standardized control chart based on defects per million opportunities

The target line for this chart equal to zero, and the control limits are (LCL=-3) and (UCL=+3).

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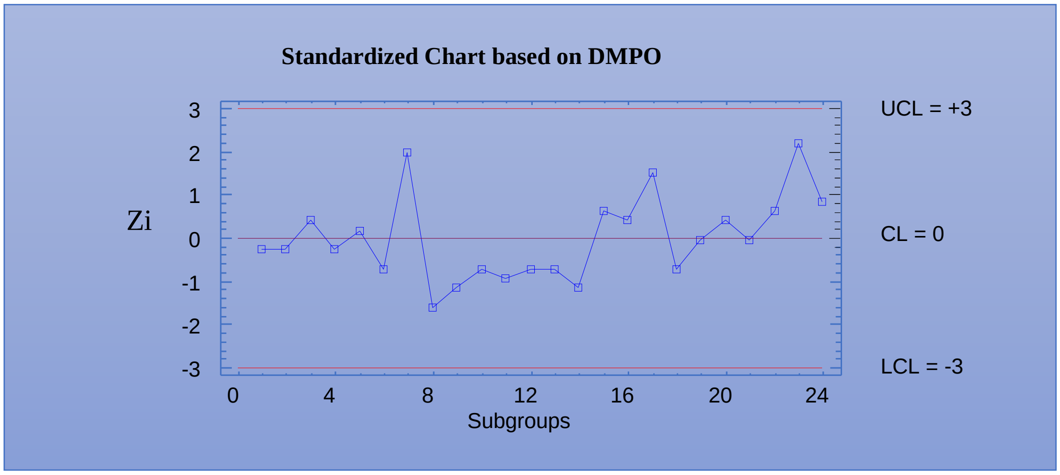

Figure 3: (Standardized control chart based on defects per million opportunities- chart)

From figure (3) we observe that all points are located within the control limits according to the statistical analysis which means that the data of table (1) are appropriate for this chart. This means that we can rely on the chart and use it for the future to control.

Conclusion

This article provided a procedure to Construction of New Standardized Control Chart based on defects per million opportunities. Using example, it was found that the examined processes were in control on both charts .The chart suggested herein may be useful for companies practicing Six Sigma process. These charts can be used to replace existing Shewhart (1931) control charts implemented when companies first started implementing Six Sigma.

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